Ontario

FUTURE SCENARIOS FOR ONTARIO

The Environment

85-2107/

Technical Report Documentation Page

MTC Report Number	ISBN Number	Other Document Number	Date
SP 009	0-7743-8990-7	ISSN 0-226-9414	Jan. 1984

Title: Future Scenarios for Ontario -- The Environment

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Published by:	Client Group:
The Transportation Technology and Energy Branch, MTC	The Outlooks Office, Strategic Policy Secretariat, MTC
Participating Agencies:	

Abstract:

This report attempts to predict the future physical environment of Ontario, with reference to the global scene, up to 2050. The first part deals with some definitions and approaches for considering the natural environment. The main body involves an attempt to foretell the future under economic low- and high-growth situations considering changes in climate; hydrology and sea-level; forest, soil and agricultural responses; Great Lakes water levels and quality; acid deposition and other air pollution; and other pollution and toxic waste problems.

Key Words: Environmental stability, change, conservation, protection; low-growth/high-growth scenario

Comments:

Distribution: by request

Copyright Status: Crown copyright

FUTURE SCENARIOS FOR ONTARIO

-- The Environment --

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Prepared for
The Outlooks Office
Strategic Policy Secretariat, MTC

Published by
The Transportation Technology and Energy Branch
Ontario Ministry of Transportation and Communications
Hon. James W. Snow, Minister
H.F. Gilbert, Deputy Minister

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For additional copies, write:
The Editor, Technical Publicatiions
Ontario Ministry of Transportation and Communications
1201 Wilson Avenue
Downsview, Ontario
Canada M3M 1J8

January 1984

FOREWORD

As part of the Transportation Outlooks project, seven papers were commissioned, dealing with well-defined themes of major significance to the future development of Ontario. Under the main heading Future Scenarios for Ontario, the titles of the papers are as follows:

1/ The Environment
2/ Resources Sector
3/ Production
4/ Multinational Corporations
5/ Social Values and Behaviour
6/ Political Change
7/ Preliminary Assessment of New Technologies

The papers were commissioned from experts, several of them of national or international renown, in various fields. It is expected that their work, and additional material related to it, will be used in the development of a number of alternative scenarios of Ontario's prospects. The main objectives are to stimulate thinking about the future and to elicit feedback from MTC planners and other users of such information in order to guide further studies of the future that are both relevant and timely.

It should be noted that these papers, which were completed in June 1982, are primarily the speculations or opinions of experts, not statements of fact. It should also be clear that a different choice of experts would have produced another set of opinions. Part of the process of anticipating future change is the painstaking analysis of detail, including quantitative information, and the expert assessment of emerging and disappearing trends and other qualitative information. Another part is the careful integration and synthesis of all these different types of information. Futures research requires the involvement and participation of all users to improve on the application of futures information to current decision-making.

Most of the reports delineate events as they would develop if Ontario, Canada, and the world were to follow two broadly different futures: low growth and high growth, as described in the following.

Low Growth

This future assumes an economic environment characterized by continued slow economic growth and attempts to reinforce the existing industrial structures globally and locally. The gap between North and South continues to widen and there is little change in conditions in the Third World. Also, relations between East and West continue to be strained. At the same time, attempts to liberalize trade and capital movements as well as reform the international monetary system will be piecemeal and sporadic.

High Growth

The main features of this environment are more rapid economic growth and attempts to harness the new technologies (e.g., micro-electronics, biotechnology, oceanography, etc.) in building a new industrial structure globally and locally. The assumptions include greater co-operation between East and West, and North and South, with rapid improvements in the conditions of the Third World. At the same time, there will be strong and relatively successful attempts to liberalize trade and capital movements as well as reform the international monetary system.

Two of the reports are based on different pre-conditions. In the case of Preliminary Assessment of New Technologies, the two scenarios were simply omitted, and an assessment was done of the potential of developing a high-technology future for Ontario. The paper Political Change deals with two main scenarios and a third scenario which considers an overlay on each of the preceding two. One pre-condition -- in effect, an amalgamation of two alternatives -- was given for this paper and is as follows.

Assume a competitive world environment (politically and economically) with slow rates of economic growth for most nations, a high priority for more economically successful countries to re-industrialize using high technology, and serious international competition for resources and markets. There will be winners and losers nationally, as well as by and within industrial sectors.

ABSTRACT

This report attempts to predict the future physical environment of Ontario, with reference to the global scene, up to 2050.

The first part of the paper deals with some definitions and approaches for considering the natural environment. The stability of the environment is discussed, and different forms of environmental change are classified. Mention is made of the present state of Ontario's environment.

The main body of this paper involves an attempt to foretell the future under economic low- and high-growth situations, considering changes in the following:

- climate,
- hydrology and sea-level;
- forest, soil and agricultural responses;
- Great Lakes water levels and quality;
- acid deposition and other air pollution; and
- other pollution and toxic waste problems.

TABLE OF CONTENTS

PAGE

FOREWORD TO THE SERIES ii

ABSTRACT iv

LIST OF TABLES AND FIGURES vi

1/ INTRODUCTION 1

1.1/ Definitions 1
1.2/ Environmental Stability and Change 2
1.3/ Important Proviso 5

2/ A LOW-GROWTH SCENARIO FOR ENVIRONMENTAL CHANGE 6

2.1/ Climatic Change 6
2.2/ Associated Changes in Hydrology and Sea-Level 9
2.3/ Forest, Soil and Agricultural Responses 10
2.4/ Great Lakes Water Levels and Quality 11
2.5/ Acid Deposition and Other Air Pollution Effects 16
2.6/ Other Pollution and Toxic Waste Problems 19
2.7/ An Overall Appraisal of the Low-Growth Scenario 22

3/ A HIGH-GROWTH SCENARIO FOR ENVIRONMENTAL CHANGE 24

3.1/ Climatic Change 24
3.2/ Associated Changes in Hydrology and Sea-Level 26
3.3/ Forest, Soil and Agricultural Responses 27
3.4/ Great Lakes Water Levels and Quality 28
3.5/ Acid Deposition and Other Air Pollution Effects 30
3.6/ Other Pollution and Toxic Waste Problems 31
3.7/ An Overall Appraisal of the High-Growth Scenario 32

4/ ENVIRONMENTAL CONSERVATION AND PROTECTION 34

Appendix A/ Policy Positions Assumed in Scenarios 35
Appendix B/ An Evaluation of the Process Used 37
Appendix C/ A Self-Critique 39
Appendix D/ Constraints Arising from Terms of Reference. 41
Appendix E/ Policy Opportunities 42

LIST OF TABLES

PAGE

1/ Temperature Changes Expected from Various Future CO_2 Concentrations (°C) 8

2/ Selected Characteristics of the North American Great Lakes 13

3/ Recent, Target and 2020 Phosphorus Loadings of the Great Lakes (after PLUARG) (metric tonnes (t) per annum load). 16

4/ Irradiated Fuel Quantities 21

5/ Possible Temperature Rises by 2050 on High-Growth Assumption Due to CO_2 and Other Trace Gases (°C) 25

LIST OF FIGURES

1/ Variation of CO_2 Concentration (Parts per Million by Volume) at Selected Stations Since 1958. 7

2/ Monthly and Yearly Mean Water Levels of the Great Lakes Since 1948 12

3/ Annual Average Acidity (pH) of Precipitation in North America During 1979. 18

1/ INTRODUCTION

1.1/ Definitions

The components of the natural environment, viz.

- air, water and climate;
- the earth's gravitational, magnetic and electrical fields;
- land, including soil, subsoil and bedrock; and
- biota, i.e., plant and animal communities,

form a single system. Each element interacts with its neighbours. The central fact about the natural environment is its interconnectedness.

There are several ways of looking at this natural complex. Each represents a partial view of the whole, because attention is focussed on some special component or spatial domain.

One such approach puts the living communities at the centre. The plants and animals, and their interactions with soil, water and climate, collectively form the ecosystem, a term often used synonymously with environment. Little attention is given to those parts of the overall system that do not obviously interact with the living organisms. This concept can be extended to include man, and his ability to modify and exploit the ecosystem. The term the human ecosystem is often used to cover this notion.

Another approach puts climate at the centre, and considers the climatic system. This includes all components of the environment that interact significantly with the atmosphere (e.g., plants, soil, ice and water bodies). Another, and related concept is that of the hydrologic cycle, which focusses on water.

Notwithstanding such partial approaches, understanding of the overall environmental system is necessary if one is to move towards comprehensive management. Present-day arrangements make such management difficult. Governments have typically divided the environment between portfolios and often different levels of government separate resource development from environmental management.

1.2/ Environmental Stability and Change

Natural environments are typically very stable. They have evolved so as to be resistant to the effects of stress or disaster. If catastrophe occurs, rapid repair mechanisms come into play. Hence, environmental change is largely, though not entirely, associated with the restoration of stability. In some ways, natural ecosystems resemble the human body in its capacity to restore health and good order after disturbance. In Canada, this is seen most spectacularly in the role of fire in the Boreal Forest (which covers nearly all Ontario north of a line from Thunder Bay to the Ottawa River). This forest was systematically burned over by lightning-set fires long before human interference began. Fairly rapid repair of the burned areas by natural succession was part of the forest's strategy for survival.

Human ecosystems are much less stable. The economic exploitation of forests, water bodies, soils and minerals has greatly weakened the self-healing mechanisms of nature. In Ontario this disturbance is so recent, usually less than a century and a half, that evidences of environmental change are visible almost everywhere. Much of this change is associated with human insults that natural ecosystems cannot easily cope with, for example, the release of toxic substances, the clear-cutting of forests, or the damming of rivers. The growth of cities has created intense local stresses. This is an age of unresolved conflict between man and nature.

This suggests the following classification of the forms of environmental change.

1/ **Natural changes** associated with alterations of the fundamental background order consist of two main kinds.

(a) Altered external "forcing," for example, an increased solar constant (strength of the sun's rays), or increased global volcanic activity, is one kind. By altering climate, such stimuli may effect changes in other parts of the natural environment, e.g., forest growth or lake levels.

(b) Another kind includes changes aimed at restoring the status quo in the natural environment after disturbance, e.g., forest regrowth after fire or disease, or soil regeneration after landslides.

2/ The results of human action **(anthropogenic changes)** consist of three kinds:

(a) changes due to legitimate exploitation of nature, such as resource exploitation (e.g., forest cutting for timber and pulpwood, or minerals extraction), clearance of land for agriculture, damming and diversion of streams for hydroelectric power or navigation, and the use of land for urban development, highways and airfields;

(b) adverse effects due to unwise or unsuitable technology, or to carelessness, which includes pollution (e.g., release of unwanted by-products, visual or noise nuisances, and acidification of lakes and streams), bad farming and forestry techniques (leading to soil erosion, stream silting, lake eutrophication, and many other effects), and careless or deliberate acts of destruction (man-set forest fires and removal of tree stands); and

(c) effects produced by efforts to correct past errors (e.g., reforestation of eroded watersheds, shelter-belt plantations, and anti-pollution measures).

The term environmental quality is a recent and unfortunate usage, expressing the idea that the changes under 2(b) represent degradation of an initially pure or clean environment. These terms involve value judgements with no scientific basis. In any case, the major damage to the environment has come under 2(a). The clearance of land for farming and the cutting of forests to supply timber and wood pulp are economically necessary and desirable actions. But they have undoubtedly done more ecological damage to the environment than has pollution (which is the form of environmental insult normally called to mind by the word "quality"). By comparison with the effects of legitimate resource exploitation, pollution and urbanization are limited in impact, though by no means negligible.

The combined effect of all these changes has significantly altered the map of Ontario. Much of the original forest is gone, and what remains is in need of attention. There has been extensive soil erosion and loss of productivity. Much former agricultural land has been abandoned, or allowed to deteriorate. The streams and lakes have had their hydrological regime altered, and their waters are heavily polluted in many areas. Acid precipitation has seriously damaged fish populations over much of the province. Urbanization has created pockets of pollution, and devours good agricultural land. Much of this change was the inevitable consequence of rapid colonization. Much of it represents the legitimate impact of a population of eight million human beings. But a good deal of what has been lost, and is still being lost, arose from poor technology, ignorance and greed. There is now a wide public consensus that better methods should be used in the future.

The prediction of future environmental change is at least as difficult as the prediction of the future human economy. In the following scenarios, I have found it possible to give quantitative estimates only for natural changes of Type 1(a) above. Changes that will arise from human actions have been treated qualitatively, for the most part. The treatment will deal in each case with:

- climatic change, if any;
- associated changes in hydrology and sea-level;
- forest, soil and agricultural responses;
- Great Lakes water levels and quality;
- acid rain and other air pollution effects; and
- other pollution and toxic waste problems.

1.3/ Important Proviso

The following scenarios are written in accordance with the two economic and social scenarios suggested. I have deliberately chosen what might be called the fast climatic evolution option in writing the text. This assumes that the climate advances to its equilibrium condition in pace with the carbon dioxide (CO_2) and associated absorbers.

There is very recent, but convincing, evidence that the heat capacity of the deep oceans may retard these changes, especially if the CO_2 increase is rapid (high-growth case). They are still expected to occur, but may not achieve full development until several decades (conceivably a half-century) after the CO_2 increase.

Hence, the scenarios for 2050 may actually be appropriate for a later date, conceivably as late as 2100. If so, the changes by 2025 will also be much smaller -- perhaps no more than one-third -- than those proposed in the scenarios. Reminders of this have been inserted into the text. The delay is likely to be more significant in the case of the high-growth scenario.

The scenarios should not be used without this proviso being attached.

2/ A LOW-GROWTH SCENARIO FOR ENVIRONMENTAL CHANGE

2.1/ Climatic Change

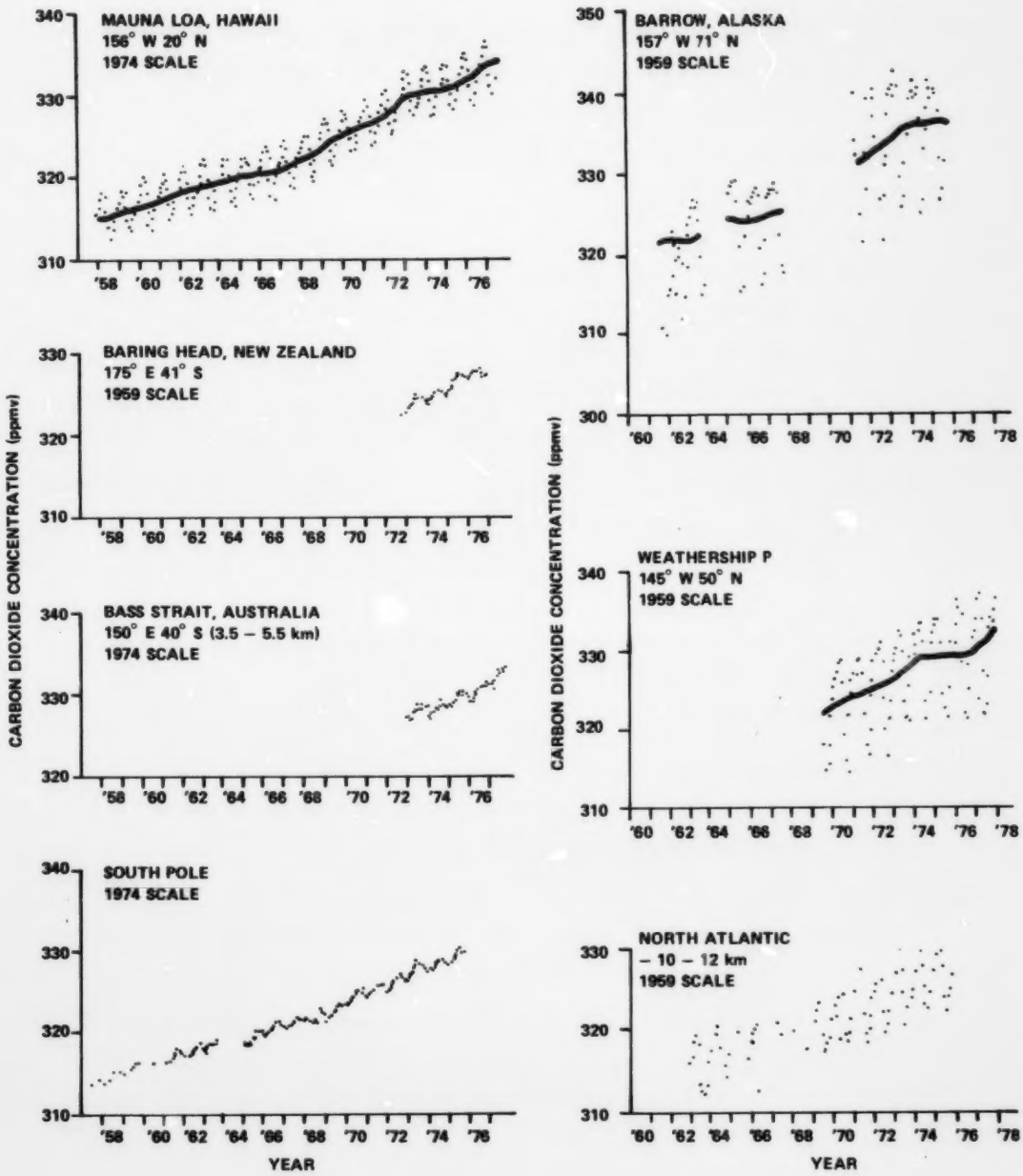
Ontario's climate is controlled by world-scale processes, not local circumstances. Even in the low-growth case, climatic change can be expected to occur by the year 2050, since significant world-wide changes in the composition of the atmosphere will have arisen. These will have resulted from continued burning of fossil fuels, from the release of certain stable synthetic compounds, and from changes in the atmospheric particle load. Some particulars are given in the following.

- **It is possible that carbon dioxide concentration [CO_2]**, will have risen to at least 150% of its present level (approximately 340 parts per million by volume [ppmv] of the air), i.e., to 500 ppmv (Figure 1). This level is likely to be reached if total burning of fossil fuel increases above 1982 levels by only 2.0% per annum. Since there may well be net CO_2 releases from world forest cutting or soil humus wastage, and since use of fossil fuel increased between 1860 and 1970 at 5.3% per annum, this figure of 500 ppmv is probably a minimum for 2050. In what follows it will, hence, be assumed that for the low-growth case

  <u>[CO_2] will be in the range of 500 to 600 ppmv in 2050.</u>

- **Certain other climatically-important gases** will also have increased world-wide. These include various synthetic pollutants, such as the chlorofluoromethanes and other halocarbons, that have effects on climate like that of CO_2. Also increased will be the concentration of nitrous oxide, [N_2O], because of increased use of nitrogen fertilizers. It is not possible to be exact about the levels to be attained by all these gases. Instead, it will be assumed that their effect will augment the climatic effect of CO_2 buildup by 25% to 50%. In other words, for the purpose of this scenario, it will be assumed that

  <u>[CO_2] will affect climate as if its value lay in the range of 625 to 900 ppmv in 2050.</u>



NOTE: 1/ TWO SLIGHTLY DIFFERENT CALIBRATION SCALES ARE USED, BUT THE UPWARD TREND IS UNAFFECTED THEREBY.

2/ A REGULAR SEASONAL VARIATION IS ALSO VISIBLE WITH MAXIMUM AMPLITUDE IN NORTHERN HEMISPHERIC HIGH LATITUDES (FROM DATA SUPPLIED BY WMO).

Figure 1/ Variation of CO_2 Concentration (Parts per Million by Volume) at Selected Stations Since 1958.

- **Particle loading of the atmosphere** arises mainly from injections of volcanic debris into the stratosphere. These may have the effect of slightly reducing world temperatures. There is some evidence that explosive volcanic activity is increasing, but there is no adequate basis yet for predicting it. Anthropogenic dust-loading of the troposphere may also be increasing, but no clear picture has yet emerged as to its effect. Hence, in this scenario it will be assumed that

  particle loading of the atmosphere may reduce the CO_2 warming, but to an unpredictable extent.

The climatic effects of these changes, calculable from mathematical models, will include a temperature increase; a change in rainfall, snowfall, soil moisture and run-off; and associated changes in oceanic conditions. The model results used here are those of the Geophysical Fluid Dynamics Laboratory, Princeton, N.J. (S. Manabe and R.J. Stouffer). For a 625 to 900 ppmv level of CO_2, the rises of mean annual air temperature (°C) may be as in Table 1.

Table 1/ Temperature Changes Expected from Various Future CO_2 Concentrations (°C)

CO_2 Concentration	Region					
$[CO_2]$	Windsor-Kingston (~ 45°)		Thunder Bay-Sudbury (~ 50°N)		Hudson Bay Shore (~ 57°N)	
	Summer	Winter	Summer	Winter	Summer	Winter
625 ppmv	+1.0	+3.0	+2.0	+4.0	+2.0	+5.0
750 ppmv	+3.0	+4.0	+3.0	+4.5	+3.0	+5.5
900 ppmv	+3.5	+5.0	+3.5	+5.5	+4.0	+6.0
1200 ppmv	+5.0	+6.5	+5.0	+7.5	+5.0	+9.0

For a concentration of CO_2 of 625 ppmv, this table, hence indicates a rise of summer temperatures from 1°C to 2°C, and of winter temperatures from 3°C in the south to 5°C in the far north. At 900 ppmv, the warming would be significantly higher. Conservatively, it seems best to consider the impact of the lowest of the predicted concentrations, i.e., 625 ppmv. These changes are likely to produce a reduction in heating degree-days (below 18°C) of about 10% to 15%, according to location, with a smaller increase in summer cooling degree-days. Hence, a significant saving in energy costs is probable.

Rainfall and snowfall are also likely to change, but less strikingly. A small increase in summer rainfall may be realized. The snow-melt period may come 10 to 15 days earlier than today, and winter snow-cover, on the average, 5 to 10 days later. Ice conditions along the Hudson and James Bay coasts will also improve.

These climatic changes will, at first, be gradual, and will later accelerate. By the year 2000, little change will have been observed, and the large year-to-year differences of weather will mask the trend, at least until late in the period. By 2025, however, the upward trend of temperature should be obvious; about three-fifths of the increases shown in Table 1 should have occurred.

Two factors may delay these effects. The model used ignores the possible retarding effect of ocean heat storage on the warming. It also disregards possible particle cooling effects. The ocean effect is probably negligible for the low-growth scenario, but the same may not be true of particles; much depends on the unknown future incidence of volcanic eruptions. It is also possible that other natural fluctuations will mask part of their expected changes, especially early in the period.

2.2/ Associated Changes in Hydrology and Sea-Level

In rivers and streams, the freshet may be 10 to 15 days earlier by 2050, and the spring run-off may have increased by 5% to 10%. This has implications for hydroelectric development. Late summer discharges may be

slightly reduced. Large inter-annual differences will continue. There may also be small but significant changes in ground water regime. About three-fifths of these changes will be visible by 2025.

Sea level has risen world-wide by 10 cm in the past century, and the increase is likely to continue. By 2050 a further rise of 40 cm to 60 cm is likely, of which 25 cm to 35 cm may have occurred by 2025. In the period 1982 to 2000, a rise of less than 5 cm is probable. These figures will be offset along the Hudson and James Bay coasts by continued coastal uplift, currently at the rate of approximately 10 cm/decade.

The rise of sea-level is believed to be due to:

- expansion of the upper layers of the ocean due to warming, and
- to melting of the world's glaciers, chiefly in Greenland and Antarctica.

The above figures assume that both processes will continue, and later accelerate.

2.3/ Forest, Soil and Agricultural Responses

The postulated climatic changes should be favourable to forest increment, though some changes in industrial practice may be called for, due to changes in snow-cover and stream regime. A slight but significant decrease in surface wetness should be perceptible late in the period, from 2010 to 2050, with some drying out and oxidation of organic terrain.

Rising temperatures and decreasing surface wetness have serious implications for forest protection. Both insect infestation and forest fires, which in bad years already damage as much forest as the commercial cut, are likely to increase. Conditions in dry summers (which will increase in frequency, especially late in the period) may become very difficult. By 2025, <u>average</u> warmth and dryness may be akin to those of present-day <u>bad</u> years. The danger may be partly offset by an increase in winter snowfall, but this must be regarded as a serious future problem.

Agriculture should, on balance, benefit from the expected changes. By 2050, growing degree-days (above 5°C) may have increased by 10% to 25%, dependent on location. Half of this improvement may have occurred by 2025. Hence, a significant gain in length and effectiveness of the growing season may have occurred. This opens up the prospect that corn-belt style farming will be possible throughout southern Ontario.

On the other hand, the greater length and warmth of the growing season implies greater soil moisture deficits in the latter part of the summer. In the south this, in turn, argues for a significant increase in demand for field irrigation. In northern Ontario, on the other hand, there is often an excess of soil moisture even in late summer, and the change may be beneficial in most summers.

No dramatic change in other soil conditions is foreseen. Losses of soil carbon, widely reported to be still in progress in Canadian farming areas, may tend to accelerate if soil temperatures rise, as they should under the postulated conditions.

Of different origin, the loss of agricultural land to urban and industrial uses will continue throughout the period, but is unlikely to accelerate. Barring public action to arrest the change, conversion of most of the remaining fruitbelt land between Hamilton and Niagara Falls seems inevitable.

2.4/ Great Lakes Water Levels and Quality

Water levels (and volumes) in the Great Lakes are subject to annual and longer-term changes, mainly due to climatic fluctuations across the Basin. They are of great importance for shoreline protection, ice regime, power development and navigation (including harbour facilities). They also have some effect on water quality. Figure 2 shows how they have varied since 1948. Levels in all the lakes vary more or less in phase. The largest changes occur in Lakes Huron and Michigan, and Georgian Bay. High levels occurred in the early 1950s and 1970s, with lowest levels in the early 1960s. These changes respond to variations in input from stream run-off, plus precipitation directly into the lakes, and to outputs in the form of discharge to the St. Lawrence (at the Iroquois control dam) and evaporation (which is large). Table 2 gives basic physical characteristics for the system.

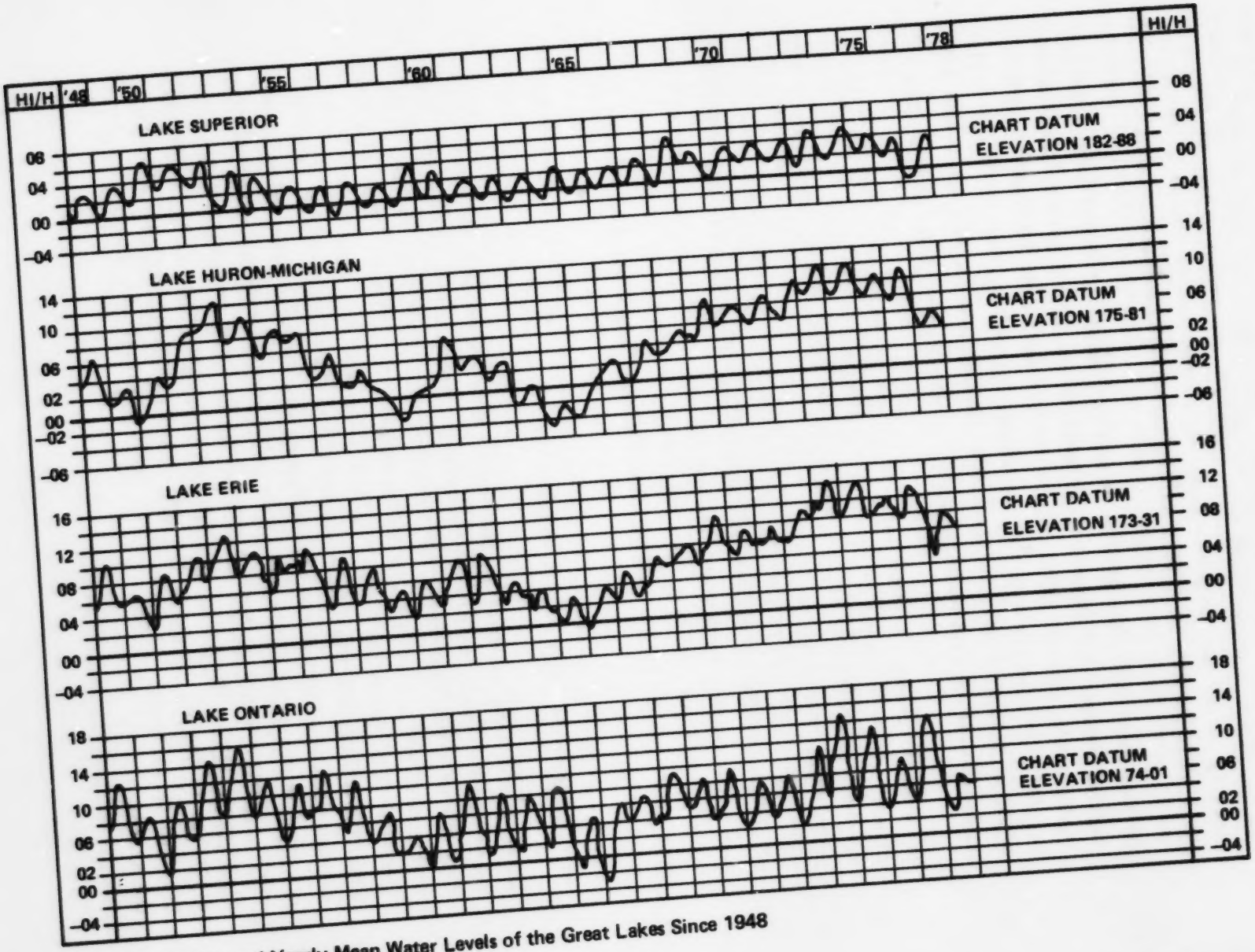


Figure 2/ Monthly and Yearly Mean Water Levels of the Great Lakes Since 1948

Table 2/ Selected Characteristics of the North American Great Lakes

Lake	Lake Area[1] (km^2)	Area of Drainage Basin (km^2)	Elevation Above Sea-Level[1] (m)	Volume[2] (km^3)	Mean Depth[1] (m)	Maximum Depth[1] (m)	Mean Discharge[1] (m^3/s)	Calculated Average Hydraulic Detention Time[3] (yr)	Total Dissolved Solids 1968[4] (ppm)
Superior	82 103	125 356	183.6	12 000	149.0	406.3	2 076	189.0	52
Michigan	57 757	118 104	176.9	5 760	85.0	281.3	1 558	30.8	150
Huron	59 570	131 313	176.9	4 600	59.4	228.6	5 038	-	118
Erie	25 667	58 793	174.4	540	18.9	64.0	5 545	2.6	198
Ontario	19 010	63 973	75.0	1 720	86.3	244.4	6 624	7.8	194

[1] Physical data from: Ragotzkie, R.A., "The Great Lakes Rediscovered," American Scientist, 62, 1974, 454-565.

[2] Volume data from: Hutchinson, G.e., A Treatise on Limnology, John Wiley and Sons, New York, 1957, p. 169.

[3] Hydraulic detention data from: Rainey, R.H., "Natural Displacement of Pollution from the Great Lakes, "Science, 155, 1967, 1242-1243.

[4] Chemical data from: Weiler, R.R. and V.K. Chawla, "Dissolved Mineral Quality of Great Lakes Waters," Oric, 12th Conf. Great Lakes Res., University of Michigan, Great Lakes Res. Dive., 1969, pp. 801-818.

The suggestion of a 20-year cycle in water levels is not reliable for prediction, though it is paralleled by similar quasi-periodic rainfall variations in the U.S. midwest and plains states. If it were to be maintained through the period of this scenario, water levels would be high again in the 1990s, 2010s and 2030s. Few hydrologists would trust such guesses, and no climatologist could support them with adequate data or predictions. The climatic predictions of Section 2.1 suggest no significant overall change in water levels.

Also of great economic importance are:

- ice conditions on the lakes, in relation to navigation and shoreline damage; and

- short storm-induced surges or seiches that lead to brief but sometimes catastrophic rises or falls of water level at either end of Lakes Erie and Ontario (and, to a lesser extent, on the other lakes).

The changes of climate postulated in Section 2.1 may slightly reduce both these hazards, especially after 2025. In any case, no worsening is foreseen.

Water quality in the Great Lakes is affected by urban industrial and rural pollution from sources within the territories of two sovereign countries: Canada and the U.S. The future course of this pollution will depend:

- on population increase and economic growth in the Basin area; and
- on ameliorative actions by federal, state and provincial governments, industry and individuals.

The latter actions will take place within the framework of the 1978 Great Lakes Water Quality Agreement (GLWA), of which the full implementation will stabilize and then improve the major pollution problems. In this low-growth scenario, it is assumed that this will, in fact be feasible, and that the objectives now being established will be realized, completely or partially, within the period 1982 to 2050.

Concern about pollution of these waters has gone through three stages:

1/ anxiety about microbial contamination from improperly-treated sewage -- not yet fully abated;

2/ a later period, mostly post-1960, in which the main worry was the eutrophication (premature biological aging) of the lakes due to inflow of phosphorus and other compounds from domestic, industrial and agricultural sources; and

3/ a very recent concern about toxic chemicals (heavy metals and organics) being released into the lakes from industrial sources.

It is probable that by 2050, and possibly by 2025, pollution of Type 1 will have been largely removed, even on the assumptions of the low-growth scenario. Item 2 involves, primarily, the control of phosphorus.

The author accepts the 1978 recommendations of the International Reference Group on Great Lakes Pollution Activities from Land Use Activities (PLUARG report), which were supported by the International Joint Commission (IJC) in 1980. Table 3 shows both the recommended targets for future phosphorus load and probable actual loads in 2020, corresponding to three different permitted phosphorus levels.

By 2020, if the GLWA measures are followed up, phosphorus levels may be reduced to near the acceptable target levels, except in Lake Ontario. In practice, there is likely to be some slippage. By 2050, the targets may well be reached, if political conditions allow.

Less optimistic conclusions are reached in the case of the toxic pollutants. It may be assumed that by 2000, and at the latest 2025, fairly effective controls at point sources will be in place in the key jurisdictions with respect to the heavy metals and toxic organics. But significant pollution also comes from diffuse sources (e.g., sediment loads in streams entering the lakes, coastal erosion, and direct run-off from agricultural land). There are also hazards from such organic pollutants as the polychlorinated biphenyls (PCBs), mirex, the dioxins, and from asbestos fibre (in Lake Superior). Large reservoirs of industrial PCBs,

Table 3/ Recent, Target and 2020 Phosphorus Loadings of the Great Lakes (after PLUARG) (metric tonnes (t) per annum load)

Item	Lake				
	Superior	Michigan	Huron	Erie	Ontario
1976 load	6445	8241	7301	25 919	15 336
Target load	4000	4900	4400	11 000	7 000
Reduction scenarios, 2020					
(i) STPs at 1 mg/L	4000	5300	4700	14 700	11 000
(ii) STPs at 0.5 mg/L	-	4700	4500	12 600	9 000
(iii) STPs at 0.3 mg/L	-	-	-	11 900	8 300

Note:

1/ STP = sewage treatment plant, with specified permitted levels per litre of phosphorus output.

2/ Dashes indicate that target will be reached, or virtually so, in less stringent scenarios.

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lead and mercury exist in the lake sediments, especially in Lakes St. Clair, Erie and Ontario. The possibility that these materials will be mobilized will remain until 2050 and beyond. It is best to conclude that the threat from toxic pollutants will remain near present levels throughout the period 1982 to 2050.

2.5/ Acid Deposition and Other Air Pollution Effects

Acid deposition (i.e., rain, snow and dry deposition) currently affects the entire province, and the impact on lake and stream ecosystems has

been moderate to severe north of the Shield limit, roughly a line from Gananoque to Penetanguishene, thence north-westward across Georgian Bay to Sault Ste. Marie (excluding the Manitoulin Islands) and onwards to the Rainy lakes. South of this line (and also east of a line from Ottawa to Brockville), extensive limestone and calcareous soils shield the water bodies from the effects of the high acidity (low pH). As Figure 3 shows, precipitation (rain and snow) is most acid (lowest pH) in south-western Ontario, but values are below "natural" levels (pH 5.0 to 5.6) over the whole province. Individual rainstorms may have pH values of 3.0 to 3.5.

The acidity arises from far-travelled pollutants, chiefly sulphur dioxide (SO_2) and oxides of single nitrogen (NO_x). These are emitted from coal-fired power stations, metal smelters and refineries, cars, aircraft and domestic chimneys. The area responsible includes a large part of the U.S. east of the Great Plains, as well as southern and central Ontario itself.

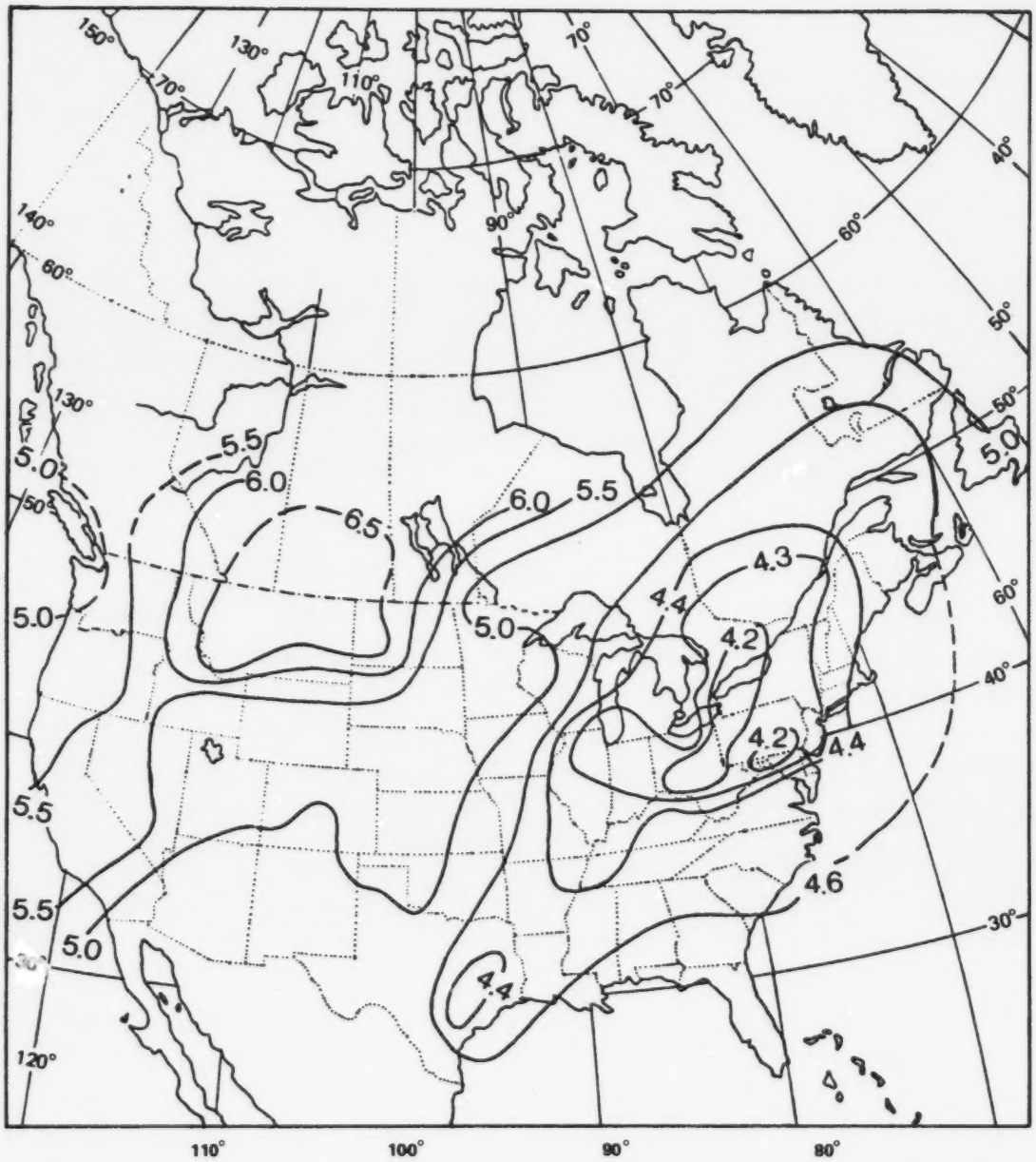
Prediction of the future course of the acidity depends on the efforts now being made to contain it. Under the recent Memorandum of Intent between Canada and the United States, a detailed analysis of causes and effects has been carried out, and the results are now being scrutinized so as to form the basis of action programmes. Unfortunately, there is strong political resistance in the United States to any curbs on the power and metal smelting industries, and, also, a movement to relax controls on NO_x emissions from cars.

In the circumstances, it seems likely:

- that only a slow reduction in SO_2 and NO_x emissions (per tonne of fuel consumed) will occur upwind from Ontario, and over the province itself; and

- that the slowness of growth will, nevertheless, require only a slow increase in total fuel consumption, and only a slow shift into high sulphur fuels.

This may mean that the sharp increase in acidity will be arrested within the next two decades. It is unlikely, however, that any marked recovery



NOTE: 1/ BASED ON OBSERVATIONS BY CANADIAN APN AND CANSAP NETWORKS AND AMERICAN MAP3S AND NADP NETWORKS.

2/ AN ISOLINE IS DASHED WHERE UNCERTAINTIES IN ITS POSITION ARE GREAT DUE TO LACK OF DATA.

3/ ISSUED BY THE ATMOSPHERIC ENVIRONMENT SERVICE, MAY 1981.

Figure 3/ Annual Average Acidity (pH) of Precipitation in North America During 1979

of the ecosystems will be achieved by 2000 or even 2025, even if deliberate management is undertaken. By the year 2050, there may be a significant improvement.

Other air pollution effects may show a similar trend. The major environmental problem (as distinct from local health effects) is the effect of such oxidants as ozone (O_3) on crops and vegetation. These oxidants are common in photochemical smog, now widespread in the Great lakes industrial area, with U.S. emissions contributing significantly. Present-day regulations permit some control of this nuisance. It may be assumed that the problem will remain much as at present throughout the period 1982 to 2050. The low-growth scenario would, nevertheless, permit fairly complete control by 2050 if the political will exists in the jurisdictions responsible.

2.6/ Other Pollution and Toxic Waste Problems

Solid and liquid wastes from municipal and industrial sources have been a troublesome problem for the province in the past decade. Strictly speaking, these are not environmental problems. They arise from a failure to provide ahead of time for technical management. They do, however, touch on the natural environment in the following chief ways:

- It is difficult to find environmentally-acceptable sites for treatment or disposal of the wastes.

- Overspills from disposal or processing sites may produce local air or water pollution problems.

The South Cayuga episode showed that local populations remain extremely sensitive to this issue. Even under the low-growth scenario, solutions may have to be imposed. For this reason, the problem seems unlikely to worsen seriously in the next 70 years, though a full solution also seems unlikely.

A solution will, similarly, have to be found for the disposal of the radioactive wastes accumulating in the province's nuclear generating stations and other nuclear installations. The same public anxieties, and

resistance to local solutions, exist as for other toxic wastes. Technical opinion is that neither the present nor the future operation of these generating stations poses a threat to the health and safety of the Ontario population. This view is obviously not shared by the public, which resists action to cope with the problem. Meanwhile, the wastes accumulate (for an overview, see The Management of Canada's Wastes, by A.M. Aikin, J.M. Harrison and F.K. Hare, 1977).

The major problem lies with the irradiated fuel taken out of the reactors at Pickering and Bruce (and that will subsequently be produced at Darlington and, perhaps, elsewhere). At present, 5000 t of this intensely-radioactive solid material is stored in the fuel bays at the generating stations. This amount is increasing at the rate of 750 t/annum. At this rate, even if no further reactors were brought on- stream, there would be about 20 000 t in some kind of storage by the year 2000, about 40 000 t by the year 2025, and about 90 000 t by 2050. Other wastes will be insignificant by comparison.

Table 4 shows Ontario Hydro's estimate of the actual future accumulation that will result from the implementation of their 1982 Interim Generation Development Plan. This assumes the coming on-stream of Pickering and Bruce B stations, the installation of new units after 1995, and the retirement (and presumably de-commissioning) of stations operated for 50 years.

Under the low-growth scenario, it seems best to assume:

- that the actual installed capacity will be less than the figures in Table 4;

- that the Atomic Energy of Canada Limited (AECL)-Hydro plan for disposal will be put into effect, probably by 2010; and

- that advanced fuel cycle options are not proceeded with.

If these conditions are met, no significant environmental impact should arise from nuclear waste management, though it will be necessary to establish good and secure transport links between the generating stations and the repository (which will probably be in northern Ontario).

Table 4/ Irradiated Fuel Quantities

(Based on 1982 Interim Generation Development Plan to 2010, and 1000 MWe per year thereafter.)

	January 1 1982	January 1 2000	January 1 2025	January 1 2050
Mass, t (whole bundle)	5000 [1]	42 000 [2]	160 000 [3]	340 000 [3]
Volume, m^3 (as stored in containers)	1800	15 000	56 000	122 000
Energy Produced, KW-h(e)	240 x 10^9	1 500 x 10^9	6 100 x 10^9	13 500 x 10^9
Installed Nuclear Capacity, MWe	5000	17 000	37 000	47 000

Source: Ontario Hydro

[1]Pickering 'A' and Bruce 'A'.

[2]In addition to [1], this includes Pickering 'B', Bruce 'B', Darlington 'A' and four 840 MWe units installed between 1995 and 1999.

[3]In addition to [2], this includes 850 MWe units installed between 2000 and 2010, and 1000 MWe per year thereafter, less the capacity of stations operated for 50 years.

2.7/ An Overall Appraisal of the Low-Growth Scenario

The main point of the foregoing account is that the major environmental issues confronting Ontario in the next three-quarters of a century are those that will arise from climatic change and the associated changes in economic opportunity, especially in agriculture, forestry and energy supply. As such, the impending changes can be met with some confidence. None of them implies any mortal threat to the province's farmers, foresters and engineers. But all of them pose a challenge; technical ingenuity and alertness will be needed to adapt to the new situation, especially in the next century.

The present-day concern with pollution is well founded, though its overall environmental impact has been exaggerated. The problem of Great Lakes water pollution will require long-term handling. Though the eutrophication and microbial aspects seem likely to be resolved fairly quickly, before 2025, one must be less optimistic about heavy metal and organic compound issues, because of large existing reservoirs of the pollutants. Existing powers of the provincial government are probably sufficient to tackle the issue. It is much more doubtful whether the federal government will be able to persuade U.S. authorities to move in concert. But 70 years is a long time and attitudes may change.

What do the changes imply with respect to life in communities, to the general quality of life, to recreation, to urban location and future industrialization? The following brief comments are offered.

- As regards **quality of life**, including life in communities, no major change seems to be in view, even at the end of the period. The Ontario of 2050 will have a natural environment not fundamentally changed from that of today. Even if population doubles, with still greater concentration on metropolitan areas, population densities will be well below those of south-east England, or the Ile de France, in which the amenities of life are currently admirable. This good condition has required, however, a far higher degree of public regulation, subsidies and amenities than Ontario is used to. A European observer of the Golden Horseshoe is struck by its untidiness and the profligate waste of

space. Maintaining or enhancing the quality of life in urbanized Ontario will depend primarily on institutional changes and awareness. Environmental change will in no serious way deter these changes.

- As regards **recreation**, such institutional awareness will need to focus on such matters as shoreline protection, guaranteed public access to larger areas of accessible shoreline and countryside, the enforcement of adequate standards of hygiene and cleanliness in the use of facilities, and other typically European (and especially Scandinavian) devices. In particular, it will be necessary to resolve the perceived conflict between recreational use and resource development. Again, nothing is foreseen in natural environmental change that affects these needs.

- As regards **urbanization** and **industrialization**, the low-growth scenario renders unlikely any major effort to alter the basic pattern of Ontario's population distribution; nor is there any need to, on environmental grounds. Population densities are far below those of European industrial areas.

3/ A HIGH-GROWTH SCENARIO FOR ENVIRONMENTAL CHANGE

3.1/ Climatic Change

In a world rapid industrial growth, it is reasonable to assume a high annual growth in energy consumption and an inevitable shift towards the less-efficient fossil fuels. Hence, the buildup of CO_2 in the atmosphere will proceed more rapidly than in the low-growth case. It is also likely that the rates of release of other radiatively-active gases (e.g., halocarbons, various organics, nitrous oxide, and methane) will accelerate. Hence, the induced warming of the atmosphere may well be more profound. Some particulars are given in the following.

- **Carbon dioxide concentration, [CO_2]**, may have risen to 175% to 200% of its present level by the year 2050, which implies a growth rate consistent with past experience of exponential rise in fuel consumption. One U.S. Department of Energy scenario assumes continued growth at 4.3%, which leads to 300% of present CO_2 levels in 2060, i.e., approximately 1000 ppmv.) If the world abandons the nuclear option, the upper figure seems feasible, though rising prices may force major economies. In any case, it will be assumed that for the high-growth case

  [CO_2] will be in the range of 600 to 750 ppmv in 2050.

  These figures neglect possible additions of CO_2 from forest and soil losses, which may bias the change towards the upper figure.

- **The effect of other climatically-important gases** cannot be estimated at all readily, except that they should enhance the CO_2-induced warming. It can be assumed that their effect can be expressed as equivalent to an addition of 25% to 50% more CO_2. In that case

  [CO_2] will affect climate as if its value lay in the range of 750 to 1125 ppmv in 2050.

- As in the low-growth case, **increased particle loads** may reduce the anticipated warming, but to what extent is unknown.

The climatic effect of these changes, calculated from the Manabe-Stouffer model of the Geophysical Fluid Dynamics Laboratory, Princeton, N.J., will include a marked rise in temperature, especially in winter; changes in rainfall, snowfall, soil moisture and run-off; considerable change in sea, lake and river ice; and altered oceanic conditions.

From Table 1 in the low-growth scenario (p. 8), the following possible temperature changes in Ontario can be inferred.

Table 5/ Possible Temperature Rises by 2050 on High-Growth Assumption Due to CO_2 and Other Trace Gases (°C)

CO_2 Concentration	Region					
$[CO_2]$	Windsor-Kingston (~ 45°N)		Thunder Bay-Sudbury (~ 50°N)		Hudson Bay Shore (~ 57°N)	
	Summer	Winter	Summer	Winter	Summer	Winter
750	+3.0	+4.0	+3.0	+4.5	+3.0	+5.5
1125	+5.0	+6.5	+5.0	+7.5	+5.0	+9.0

The figures in Table 5 suggest a dramatic change in Ontario's thermal climate, with the following main features.

- **A uniform rise of summer temperatures** from 3°C to 5°C would occur in all parts of the province. This would give Toronto a July temperature of 24°C to 26°C, a value now typical of the southern midwest of the U.S. and the southern and middle Atlantic States. In the Clay Belt, July temperatures would be 20°C to 22°C, values comparable with those now experienced in London, Kitchener and Kingston.

- **A strong rise in winter temperatures** would average 4.0°C to 6.5°C in southern areas, increasing northwards to rises of 5.5°C to 9.0°C in the most northerly areas. Hence, the harshness of the northern winter

would be greatly lessened. In Kapuskasing, for example, January temperatures would lie between -13°C and -10°C, comparable with modern conditions at Ottawa and North Bay. In Toronto, January temperatures would lie between 0°C and -2°C. In most years, snow would not lie for long, and harbour ice would be thin and intermittent.

- These rises imply reductions in heating degree-days (below 18°C) of 15% to 30%, which suggests a major saving in space heating costs. Air conditioning costs in summer, however, would rise spectacularly in southern areas. A net saving is probable, but this requires further study.

- The above changes will become detectable by 2000, and by 2025, half to three-fifths of them will have occurred.

These changes may, however, be retarded by a decade, or even by two or three decades, by the effect of the deep waters of the oceans. Hence, the results postulated for 2050 may not be fully realized until 2060, or even 2070 or 2080.

Changes of snowfall and rainfall are likely. An increase of spring and early summer rainfall is possible, though rainfall in later months of summer might be less reliable, and soil moisture deficits more severe and prolonged. Snowfall in southern Ontario would diminish, being replaced by rain or freezing rain. Snow-cover in southern areas would become less deep and less continuous than at present. In fact, from Belleville south-westward along the Ontario shore and through most south-western counties, snow-cover would be intermittent in many winters. In northern areas, however, some increase in winter snow-cover (and, hence, spring run-off) may occur. In southern areas, spring snow-melt may come 15 to 25 days earlier, and winter snow-cover 20 to 30 days later. In the north, snow-melt and snow-cover will change in the same sense, but with slightly greater changes.

3.2/ Associated Changes in Hydrology and Sea-Level

In rivers and streams, the freshet may be 15 to 30 days earlier in 2050 in the south, and freeze-up 20 to 35 days later. Freshet run-off may be

reduced. In the north, the freshet and freeze-up will alter in the same sense, but an increase in spring run-off of 10% to 20% is possible. The period of low summer flow should increase. Some decrease in inter-annual variability of winter conditions is possible.

Ice conditions in the lakes and rivers will also become markedly easier. Years of open ice in Lakes Superior and Huron will become more common. It is possible that the present complete cover on Lake Erie will be much less long lasting. The possibility exists that, in the latter part of the period (2025 to 2050), a winter ice-cover on Lake Erie will become intermittent or even vanish. Mean air temperatures around the lake will be near or above 0°C in mid-winter.

The present rise of sea-level (10 cm in the past century) will probably accelerate. A further rise of 50 cm to 100 cm by 2050 or a little later is probable because of accelerated melting of the major ice-caps. The unrelated rise of the shoreline of Hudson and James Bays will, however, offset most of this rise of sea-level in Ontario.

3.3/ Forest, Soil and Agricultural Responses

The postulated changes of climate will lead to significant changes in forest increment (and ultimately composition). Rising temperatures will favour wood formation, although in the south there may be some adverse effects due to late summer soil moisture deficits. In the north, the effects should be wholly beneficial.

The changes should stimulate a significant long-term shift of forest climates. The oak-dominated deciduous forests now confined to the Niagara Peninsula and the Lake Erie counties (with enclaves along the north shore of Lake Ontario as far east as Belleville) will find favourable conditions at least as far north as Parry Sound and Ottawa. In turn, the northern limits of species such as white and red pines, sugar maple, hemlock and beech will shift some hundreds of kilometres north. Under the present highly-disturbed conditions, these migrations will, however, take centuries, and will be barely visible by 2050.

Agriculture should benefit from the postulated changes, at the cost of certain adaptations. The temperature rises indicated (with the associated increase in frost-free period) will put northern farming areas on a basis like that of present-day eastern Ontario. Growing degree-days (above 5°C), currently in the range 1250 to 1500 in the area, should increase to 1700 to 2100, comparable with conditions in the Ottawa Valley or the Red River Valley of Manitoba. Drier conditions in late summer may lead to easier handling of soil and better ripening of crops. In southern Ontario, the effect will also be appreciable. Most areas may have growing conditions like those of the modern U.S. Corn Belt, with a need for significant increases in irrigation. In many areas, the latter may be a problem because ground water recharge is likely to be diminished below present values.

On the negative side, the forest fire hazard, in this scenario, may be far more serious than at present because of prolonged summer floor dryness. In the north, there may also be major infestations and damage to foliage.

Losses of agricultural land to urbanization and industrialization are likely to be very serious under this scenario. Shortage of mobile fuels may tend to restrict urban sprawl, but past experience suggests that the Ontario economy is very resistant to high-density development for non-residential purposes. The suburban subdivision, the concession-road villa and the country estate will remain attractive until the price of gasoline or its successors makes such residences uneconomic. It is highly unlikely that this will occur by 2000. By 2025, however, it may well be that the pressure on land will abate. If the province undertakes to develop new industrial areas, or planned communities such as Kanata, however, this may offset the above correction.

3.4/ Great Lakes Water Levels and Quality

The climatic scenario developed in Section 3.1 suggests no immediate change in the overall input to the Great Lakes by run-off. Slight increases in precipitation will be offset by longer periods of soil moisture deficit in summer, and by greater evaporation. In fact, towards the end of the period, as 2050 approaches, there may be a small decrease

in the mean annual inflow to the lakes, as well as an increase in evaporation losses. Hence, a small drop in overall lake levels may become apparent, chiefly after 2025.

Of greater significance may be the expected decrease in the thickness, extent and duration of lake ice. The expected rise in temperatures should materially shorten the season in which the lakes and connecting channels need to be closed. Lakes Erie, St. Clair and Huron, in particular, may experience striking decreases in ice-cover. Considerable coastal damage is done when high winds drive such ice ashore. This hazard may slowly diminish, especially after 2000. Overall, the lengthening of the navigation season by five to seven weeks may be considered. Lake Erie will be the problematic lake. Calculated temperatures suggest that ice may hardly form in many winters, in spite of the fact that this southernmost lake currently has the most extensive winter ice (because of its shallow depth and low heat storage). In any case, there needs to be an expert analysis of the potential impact of the hypothesized warming.

Cyclical fluctuations in overall water levels in the Great Lakes system as a whole (Figure 2) are expected to continue. Short-term seiches and surges, however, may possibly become less of a problem by 2025, and even less so by 2050. This is because the reduced winter poleward temperature gradient will tend to reduce the intensity of cold-season storms.

As in the case of the low-growth scenario, the future course of water quality in the Great Lakes will depend mainly on institutional policies, largely within the framework of the Great Lakes Water Quality Agreement (GLWA) of 1978. It will also depend on the scale and character of economic growth in Ontario and the eastern and central United States. As before, the three areas of concern are microbial contamination, the eutrophication problem, and pollution by toxic chemicals and heavy metals.

Once again, it may be assumed that microbial contamination due to imperfect sewage treatment will gradually be reduced. Even with more rapid population growth (including the possibility of new settlements), the conditions of the scenario will certainly allow the public investment

required to remove the remaining problems (chiefly in the U.S. areas) and to provide for all new growth. It is hard to believe that public opinion will accept any less adequate performance.

Reduction in phosphorus loading (and, hence, in eutrophication) should also be achieved well within the period. As Table 3 shows, if sewage treatment plants adopt a standard of 0.3 mg/L of phosphorus, the recommended maximum loadings can be achieved by 2025 or a little later. It is possible, of course, that conditions of high growth and technological change may increase the input. But there is no technical reason why the phosphorus loadings should not be brought to acceptable levels even under these conditions, certainly within the period 2025 to 2050.

Much greater problems may be created by the release of toxic chemicals and heavy metals into the lake from agricultural pesticides, industrial waste streams and dumps and, probably, from disturbed bottom sediments. If there is significant industrial growth, there will be increased danger of such toxic releases, especially if heavy industries resume their expansion in the Great Lakes Basin. At present, there are a variety of such problems -- PCBs, mirex, dioxins, lead, mercury and cadmium are conspicuous examples. There is a danger that future technological changes will add other substances to the list. By the year 2000, it is doubtful whether there will be much change. For 2025 and 2050, much will depend on policy decisions taken by the various governments, which are only now coming to grips with this aspect of environmental change.

3.5/ Acid Deposition and Other Air Pollution Effects

The acid deposition problem was described under the low-growth scenario (pp. 16 to 19). Comment here is confined to the implications of high growth.

It is probable that sustained high growth of the U.S. economy during the period will involve a large-scale expansion in the use of poor-quality coal in power generation. Supply is adequate for this purpose, and the cost of clean fuel may be prohibitive. If so, SO_2 releases upwind from Ontario will increase sharply through the period, unless the U.S. moves to require scrubbing. There may also be a substantial increase in NO_x emissions, though the increase in cost of gasoline may retard this.

Within Ontario there may be parallel changes, but the availability of clean nuclear power is higher. Hence, it may be assumed:

- that under high-growth conditions, the SO_2 and, possibly, the NO_x burdens of the air over Ontario will increase substantially over the entire period; and

- that there will be a further increase in the acidity of precipitation (of about 0.5 to 1.0 on the pH scale) and in dry deposition.

These hazards will be avoided only if there is a massive shift out of coal-fired into nuclear power generation, or if there is an immediate commitment in all jurisdictions to at-source control of SO_2 and NO_x emissions. The present trend (in the U.S.) is the opposite direction.

The trend in other forms of air pollution, especially photochemical oxidant problems, may also be unfavourable under this scenario. Such pollution is, nevertheless, more tractable to regulation. Everything will depend on the re-emergence of high public concern.

3.6/ Other Pollution and Toxic Waste Problems

The accumulation of bulky wastes from industry and municipalities may well be aggravated by the conditions of rapid economic growth. Whether in solid or liquid states, these wastes are an embarrassing management problem with significant environmental spillovers. It will remain difficult to find acceptable disposal sites or to contain toxic or noxious components successfully. Rapid growth has, in the past, always meant added volumes. It may also add to the complexity of the resultant waste stream.

As regards nuclear waste, the general remarks made under the low-growth scenario apply with even greater force to the high-growth case, with the following additions.

- The rate of expansion of nuclear installations will probably follow the Ontario Hydro projections of Table 4. The problem of disposal will, hence, be correspondingly more urgent.

- It is possible that advanced fuel cycle options will be adopted, involving fuel processing to extract Pu-239 from irradiated fuel, and the use of Th-232 as an input. The refining, fuel fabrication and new reactor installations will add to the number of sites in Ontario for which sound environmental management will be needed. The problem of waste disposal will also be more formidable.

In 1982, the future of nuclear technology is very much in doubt. If this doubt is dispelled, the above questions will have to be faced.

3.7/ An Overall Appraisal of the High-Growth Scenario

The main environmental issues confronting Ontario in the next 70 years, if there is high world economic growth, will arise from climatic change induced by the expansion of fossil fuel consumption. This change will be more pronounced than in the case of low growth. If realized, the change will have important and mainly beneficial side-effects on agriculture, fisheries, forestry, energy production and transportation, in short, on a large part of the entire provincial economy. These changes will depend on conditions outside the province. Even if Ontario's economy stagnates, the effects will still be felt.

High growth implies, however, a substantial increase in the pollution hazard, in resource exploitation and in the complexity of the waste stream from industry. If there are attempts to create new industrial and urban concentrations in various parts of the province, there will be changes in the pollution load. The above treatment assumes that the major adverse effects may be felt in pollution by toxic chemicals and heavy metals, and increasing acidity of precipitation. In the Great Lakes, the eutrophication and sewage-treatment issues should still be tractable.

A significant new environmental opportunity may present itself late in the period. Mention was made above of the improved ice conditions that should result from the milder winters expected later in the period. Mathematical modelling suggests that after 2050 the permanent pack-ice in the Arctic Ocean will begin to disperse. By that date, there may well have been a marked improvement in ice conditions in Hudson Bay, Hudson

Strait and the Labrador Sea. After 2025, there should be many good sailing years on the Hudson Bay route, at present severely limited by heavy ice. The province should consider the long-term implications of the anticipated improvement in navigation. A deep-water harbour on the James Bay or Hudson Bay coasts may become useful towards the end of the period.

The remarks made under the low-growth scenario as regards quality of life still apply: there is abundant room in Ontario for a greatly expanded population and for a much greater industrial effort. "Room" includes land for agriculture, water for domestic, agricultural and industrial purposes, and both for recreation. The perception that Ontario is pushing hard against its limits simply ignores European experience. It is possible to combine all these needs, provided that the province is able to accept the higher level of regulation and planning required.

This planning and regulation will need to protect good agricultural land (and to compensate the farmers if their equity is thereby affected, as it may well be), to prefer poorer soils for new industrialization and urban growth, and to protect shorelines. The market will not do any of these things.

4/ ENVIRONMENTAL CONSERVATION AND PROTECTION

This entire document has been prepared in response to a specific set of terms of reference that were clearly economic in nature. A few words need to be added as regards those aspects of environmental change that are not mainly economic, but arise from the need for conservation and protection.

The climatic changes foreseen under the scenarios imply significant changes in ecosystem function, dynamics and stability, such as the following.

- The rise of temperature is likely to drive northwards the limits of certain species of animals and plants. This was mentioned earlier, in the context of forestry. The changes will, however, involve other kinds of biota. Bird, insect and mammalian life may be significantly altered. There are implications here for hunters, as well as for conservationists.

- Fresh-water ecosystems are also likely to undergo substantial adjustments, quite apart from those forced by acid precipitation and other forms of pollution, or by changes in the distribution of human settlements. The complications for fisheries need to be explored.

- Wetland habitats are likely to shrink due to human encroachment. Later in the period, they may also dry out, to some extent, because of the warmer climate (and possibly drier late summers). This will have serious wildlife consequences, especially for bird migrations.

- The Hudson Bay Lowlands will be especially affected. It is likely, under the conditions of either scenario, but especially the high growth, that the accumulation of peat on these lowlands will slow down, and may even reverse. A phase of surface drying and oxidation may begin later in the period. This, again, has important habitat implications for wildlife.

The list could be substantially longer. It is important to approach the postulated changes with a conservation and protection strategy that takes them into account. A purely economic approach to the issue will be insufficient.

Appendix A/ Policy Positions Assumed in Scenarios

It has been assumed that the present powers of the Ontario and federal governments to regulate pollution, land use, Great Lakes water use, streams, fisheries, agriculture and forestry remain essentially unchanged. The attainment of various water-quality goals, in particular, depends on continued vigilance, especially as regards sewage treatment to reduce microbial and phosphorus content.

It has also been assumed that the United States will generally move more slowly and reluctantly towards effective control over pollution emissions, and towards measures taken under the Great Lakes Water Quality Agreement. Similarly, it has been thought unlikely that the U.S. will seriously pursue effective action under the Memorandum of Intent concerning acid deposition. Ontario is the prime target of U.S. failures in this respect. It is, hence, essential that Ontario continue to urge action by the Government of Canada to speed matters up in related problems, well beyond 2050, because of the long physical implementation and ecosystem recovery times.

No specific new powers for the Ontario government have been assumed. The question should be raised as to whether existing powers are adequate to achieve the following objectives.

- As time progresses, it will become essential to regulate the use of much land to safeguard future access to recreational facilities (especially shorelines), prime agricultural land, and certain ecosystems (most notably the wetlands of the province, including the entire Hudson Bay Lowlands).

- The control of toxic chemicals (including the heavy metals and radio-isotopes) will remain a high priority item, as will the choice of sites for toxic waste disposal.

- Special attention will have to be given throughout the period to the maintenance of high forest productivity, together with optimal environmental practice on all forest lands. Fire and infestation control will become even more vital.

- Agriculture will also remain in need of constant watching. In both scenarios, there are likely to be significant changes in economic opportunity throughout the existing farmed areas. Irrigation will need to be extended, which has implications for groundwater control as well as for the capacity of supply systems. The use of fertilizers and pesticides needs to be brought under firmer control.

- In the latter part of the period, quite significant changes in the northern economy will become apparent. These will include better farm prospects, enhanced forest growth, and the possible need for a deep-water port on Hudson or James Bays.

Appendix B/ An Evaluation of the Process Used

The general economic and environmental background assumed has been that described in Global 2000: Implications for Canada (G.O. Barney, P.H. Freeman and C.A. Ulinski, Pergamon Press, 1981), except that the report's findings on Canadian agriculture differ from those presented here. Future CO_2 buildup in the atmosphere has been estimated from energy-use scenarios broadly consistent with the above, notably those of the Institute for Environmental Studies, University of Toronto (R.E. Munn, 1980), the U.S. Department of Energy (R.M. Rotty and G. Marland, 1980), and the International Institute for Applied Systems Analysis (W. Hafele et al., 1980).

The associated estimates of climatic change were based on various models used at the Geophysical Fluid Dynamics Laboratory, Princeton (S. Manabe and R.J. Stouffer, 1980). These are general circulation models linking the atmosphere to the ocean, and with realistic global geography; such models incorporate two major positive feedbacks: that due to the poleward retreat of reflective snow and ice surfaces, and that due to the enhancement of the greenhouse effect by added water vapour. Simple surface energy balance models neglect the latter feedback and, hence, get much smaller temperature changes. The amplifier effect of synthetic pollutants, nitrous oxide and methane follows mainly the work of the National Center for Atmospheric Research, Boulder, Colorado (V. Ramanathan, 1975) and the Goddard Space Flight Center (Institute for Space Studies, New York, N.Y., A. Lacis, J. Hanson et al., 1981).

The above sources are quantitative, but still highly tentative. They are, in my judgement, the best scenarios available, but they should still be used with great caution.

With respect to Great Lakes water quality and quantity, I have relied mainly on the IJC International Reference Group on Great Lakes Pollution Activities from Land Use Activities (the PLUARG Report, 1978), and the IJC Report Pollution in the Great Lakes Basin from Land Use Activities (1980). I have also made use of the Ontario Ministry of Natural Resources report Great Lakes Shore Processes and Shore Protection (1981).

For acid deposition, I have mainly used papers and reports in the files of the Joint Royal Society of Canada/National Academy of Sciences Committee on Acid Precipitation, of which I was Canadian co-chairman in 1981-1982.

For forestry, I have made extensive use of the Canadian forest Congress Report The Forest Imperative (1980), plus the unpublished proceedings of the Banff Conference on Transition to Management (A. Zimmerman and F.K. Hare, 1981, co-chairmen).

In Sections 2.4 to 2.6 and 3.4 to 3.6, I have had to guess the future course of governmental decisions, and of public attitudes, at which I am highly inexpert. Hence, their level of certainty is very low.

Appendix C/ A Self-Critique

Appendix B deals with sources. At several points in the text there are warnings about uncertainty. I shall now attempt an overall critique.

First of all, it must be asserted that all scenario writing is highly uncertain, whether one uses quantitative models or just imagination. These present examples are no exceptions, depending as they do on both sources.

- In each scenario, the climatic and hydrology changes (Sections 2.1, 2.2, 3.1 and 3.2) are based on up-to-date observational data (very reliable) and on a general circulation model (GCM) of the atmosphere (with crudely-linked oceans). This model includes the all-important feedbacks (albedo, due to variable snow- and ice-cover, and water vapour, in which the CO_2 warming increases humidity, and, hence, the greenhouse effect).

  It does not explicitly include the effect of ocean currents, nor does it allow for the time required to reach the equilibrium climate described. Recent modelling suggests that this delay may amount to several decades for very large and rapid buildup of CO_2 (high-growth scenario). The proviso page stresses this. Other GCMs with an interactive ocean get similar answers to the Manabe-Stouffer model used. None of these models produce enough regional detail to be very specific about climatic changes. The effects included in the scenarios are those predicted for the latitude concerned. In Ontario, they may differ from the conditions elsewhere along the latitude belt. The Manabe-Stouffer model shows the province in the areas of stronger effect in both seasons, but this has been soft-pedalled in the present analysis. Models that do not include the water-vapour feedback (surface energy balance models) and models stressing particle buildup all get lower heating rates (Idso, Newell, and Bryson). It is my judgement that the GCMs are right, and the others wrong; that the delay time will not be significant for the low-growth scenario; and that events will pan out as predicted by the GCMs. Only the possible ocean heating delay still bothers me.

  Confidence: moderate

- In the sections (2.3 and 3.3) on forest, soil and agricultural responses, the quantitative estimates are based on my own parameterization using non-linear regression of heating degree-days against January temperature, and growing degree-days against July temperature. Snow and ice dates are similarly calculated.

  Confidence: high, if the climatic change data (Sections 2.1 and 3.1) are correct.

- Sections 2.4 and 3.4 (the Great Lakes) are based on published data of high reliability, plus the PLUARG Report. I am not expert in this question, but am satisfied that the basis is good.

  Confidence: moderate

- Sections 2.5 and 3.5 (acid deposition) are based on evidence contained in various documents prepared under the Memorandum of Intent. The scientific information is reliable. Future institutional change, however, is obscure, and again, I am inexpert.

  Confidence: moderate to low

- The topic of other pollution and toxic waste (Sections 2.6 and 3.6) is a grey area to me, except insofar as nuclear waste is concerned (where I have also consulted Ontario Hydro).

  Confidence: { non-nuclear waste: low
  nuclear waste: moderate to high

- The overall appraisal of each scenario (Sections 2.7 and 3.7) is only as good as I am, after a varied career. Hence, I give it no better than moderate to low confidence.

Appendix D/ Constraints Arising from Terms of Reference

Apart from the obvious problem of the shortness of notice (5 weeks, of which 10 days at most were available to me), the only major constraint that I experienced was due to uncertainty as to the assumptions underlying the low and high growth scenarios.

In environmental analysis, it is most often assumed that economic growth leads to increases in energy consumption. A linear relationship between Gross National Product (GNP) and per capita energy use is well established. Until recently, increases in GNP also depended linearly on increases in energy consumption, with a lower correlation. In the past seven years, this latter correlation has almost disappeared, as energy conservation measures and price rises have taken their toll. The first relationship still holds.

Nevertheless, I have assumed that both relationships are still valid, and that energy consumption will be higher under the high-growth than under the low-growth scenario, with both being higher than today's levels. I have, however, assumed growth rates in future fossil fuel consumption well below that of past experience.

Although it is possible to visualize low-energy, high-income economies, I believe that such a relationship is possible (except for oil-rich states) only for societies that have passed certain economic thresholds, particularly as regards infrastructure. Ontario already has the latter. There are highways, airfields, canals and housing. But future environmental change (notably CO_2 levels and, hence, climate) will depend on actions taken in less fortunate countries. For the next half to three-quarters of a century, I expect the less-developed countries to move heaven and earth to equip themselves with these things, especially India and China. There are no low-energy ways of realizing such ambitions. Hence, I am sure that the upward course of energy consumption will continue, and that the fossil fuel will continue to be burned.

Appendix E/ Policy Opportunities

Certain following policy opportunities arise directly from matters discussed in the text. To those listed in Appendix A, the following are added.

- There is a need for a continuing watch on environmental change, both by monitoring and by "think-tank" style operations.

- The climatic changes foreseen in both scenarios need to be taken into account in at least the following contexts:

  -- water levels and ice-cover on the Great Lakes, with implications for navigation, power development, harbour and channel installations, shoreline conservation and recreational opportunities;

  -- agricultural and forestry opportunities, techniques and marketing, including forest protection; and

  -- water supply, including groundwater use and irrigation.

- Because so many of Ontario's environmental conditions depend on U.S. or even world actions, it is vital that the province urge the federal government to act vigorously in these matters, and maintain an internal mechanism for an overview of Ontario's stake in them.

- The province is the only major customer for the CANDU nuclear technology, which will need nurturing if it is not to be lost. This is mainly a matter of energy policy, but not entirely. CANDU reactors behave in an environmentally-desirable fashion. When the present environmentalist anxieties have died down, it may well be decided that CANDU advanced fuel cycles, especially the Thorium-232 version, are the wisest course for the province, even on environmental grounds. These matters need a cool look now.

The largest policy option that I see, however, is to move into a new posture as regards environmental policy. The environmental movement

arose out of anger and indignation at pollution and resource wastage. Hence, it is seen as a protective function, touching on human health and convenience. It really ought to be seen as the positive process whereby we automatically build good environmental practice into all technical, economic and social innovations. The real object of environmental policy should be to increase economic productivity, public amenities and human welfare as a positive objective. I am confident that this can be attained well before 2025 in an advanced and humane society like ours.

Finally, I remind the reader that the changes foreseen in this document will benefit northern Ontario substantially. It is there that I anticipate maximum impact.